Concrete Engineering and Technology
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Lecture - 33
Using recycled aggregates in concrete construction

[FL] and welcome to this lecture in our module of concrete engineering and technology.

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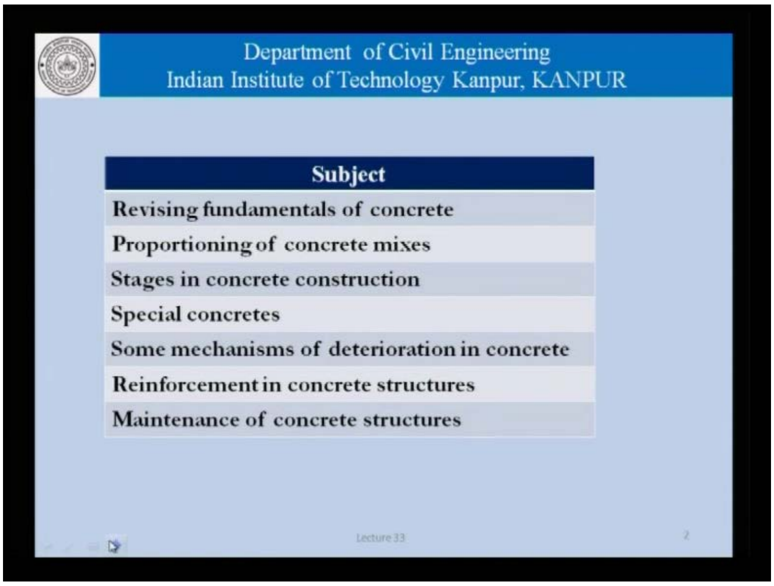

We have been talking about fundamentals of concrete, the materials that make the concrete, proportional's of mixes, stages in concrete constructions, special concretes, mechanisms of deterioration, reinforcement and maintenance and so on with the view that what is it that is a concrete engineer a person would need once you start practicing.

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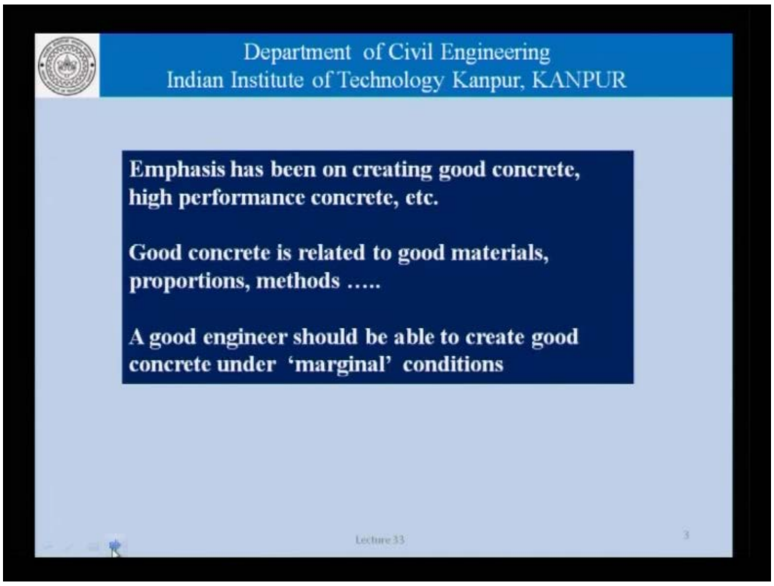

So far we have concentrated on creating good concrete, creating high performance concrete, the specifications that govern it, the quality control issues that are involved and so on. There is another important aspect to it and that is what we will touch upon today. Good concrete is related to good materials proportions and metals. We have talked about this earlier that in order to produce or in order to be able to produce good quality concrete which is a necessary condition for producing good quality concrete construction, we should have good materials, we should proportion them properly and the methods that we use should be appropriate considering the actual location of placement, the conditions of placement, the environment and so on and so forth.

What we should also emphasize and I have talked about it a little before is that a good engineer should be able to create good concrete under marginal conditions, under ideal conditions so much easier to be able to deliver in order to be able to deliver a quality product. As far as civil engineering in general is concerned and concrete engineering in particular where the work has to be done at site the material that we use is often locally available material which may or may not be of the highest quality.

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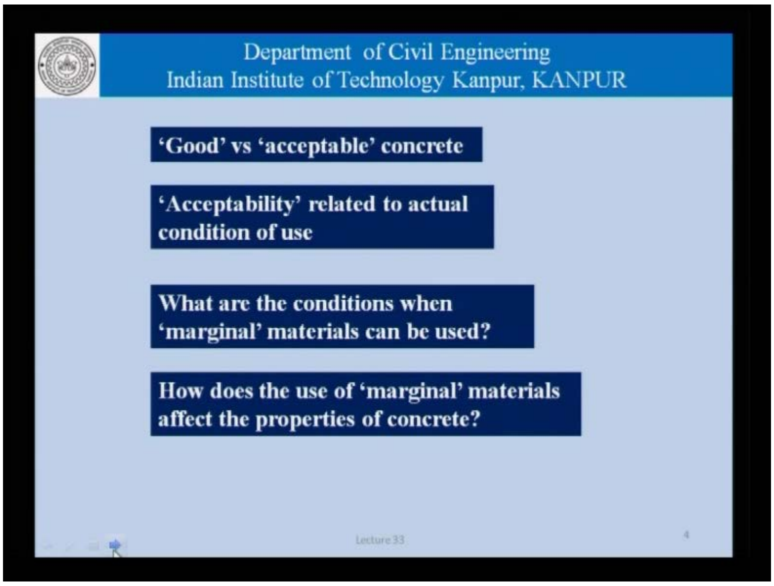

The owners on being able to deliver good quality concrete for good quality construction lies on the engineer who should be able to use marginal materials, marginal conditions of construction and yet be able to produce good quality work. Now, obviously there is a problem. The problem is good versus susceptible concrete. Of course, the very essence of this discussion in good versus acceptable is in the fact that the engineers recognize that we may not be able to produce the best quality of concrete all the time.

In fact it may not even be required to produce the best quality of concrete all the time let us say in terms of strength, there is a specification which says that well for a particular construction we need m 20 concrete, a concrete which has characteristics strength of 20 MPa or 25 MPa. We are capable of producing 40 MPa, 50 MPa kind of concrete but, for that particular application 20 MPa is acceptable.

So, acceptability and good is something which we need to think about it a little more. Acceptability is related to the actual conditions of use, the example I just gave you was on in which their structure has been designed for 20 MPa and therefore, we should deliver 20 MPa. Considering the fact that if we want to deliver more or if we deliver higher strength concrete then, there could be economic implications it could become costly and so on.

Turning the situation the other way round we must understand what are the conditions when marginal materials can be used. Marginal materials are those materials which do not qualify the tests that are normally used for identifying good quality material. So, if a material whether it is coarse aggregate or it is sand, it does not meet the requirements of good quality aggregate are there places where we can use it.

In other words, what happens if we use it? How does the use of marginal materials affect the properties of concrete? Now, the basic question is, why do we want to use marginal materials? In this course so far we have not talked of marginal materials because we were concentrating on producing good quality concrete, best possible quality of concrete all the time. But, in this lecture today we will talk about marginal materials and its use because the concrete engineer of this [the end] age one must be aware of the responsibility in terms of the environment, in terms of energy required and so on.

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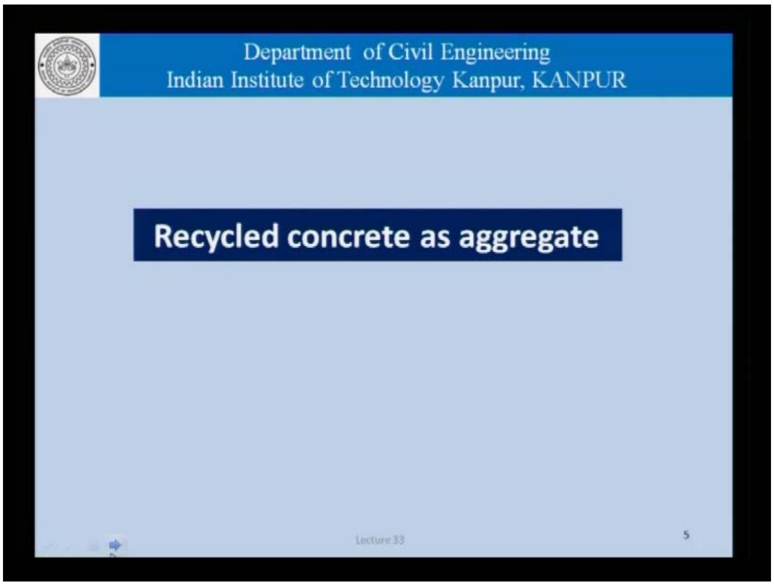

We will try to talk about using recycled concrete as an aggregate. As a backup to this discussion remember that concrete once hardened it becomes very difficult to break in fact, stronger the concrete more difficult it is to break it the demolisher concrete structure meet with high strength concrete is a challenge in itself. Therefore, the higher strength concretes that we use they become such a liability when it comes to handling them or disposing of them at the end of their service life and that is something which are concrete engineer in this day and age cannot forget. Structures have a no service life and at the end of that the structure needs to be demolished or may need to be demolished in order that a new structure can be build.

We cannot simply dump the concrete that we generate out of that demolition process the waste it is that we generate. It is our responsibility as concrete engineers to also think as to what will happen to that waste. And today's discussion even though it is largely based on using hardened concrete or broken down hardened concrete which we are calling recycled concrete as aggregate. The discussion can be extended to any such construction in demolition waste and we sometimes see in literature reference being made to construction and demolition phase as construction material. So, today's discussion will be on using recycled concrete as aggregate.

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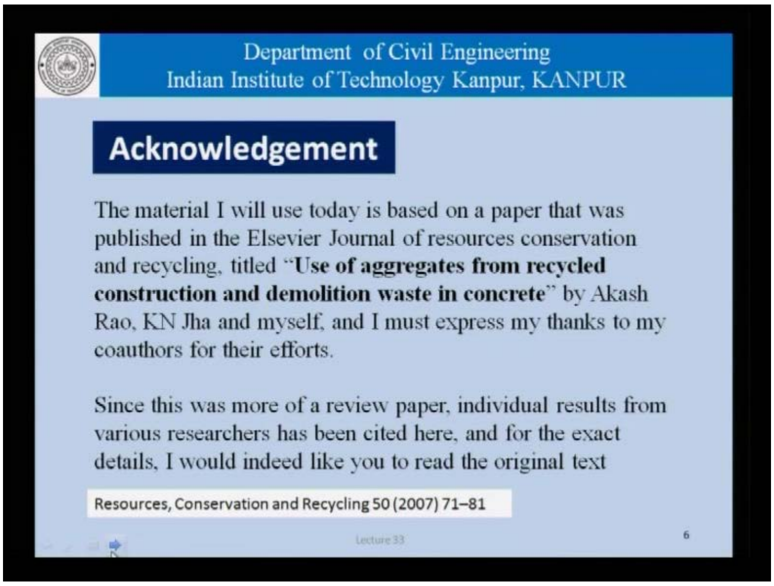

This discussion today will be largely based on a paper that was published in the Elsevier journal of resources conservation and recycling tilted use of aggregates from recycled construction and demolition waste in concrete by Akash Rao, KN Jha and myself and I must express my thanks to my co authors for their effort. Akash Rao was an M.Tech student here at IIT, Kanpur and he did his thesis in this area and professor Jha is now teaching at IIT, Delhi

Now as far as this paper is concerned it was more of a review paper where we tried to collect the information relating to various aspects of the use of recycled concrete as aggregate in fresh concrete or in new concrete. The results have been taken from various authors in the different research work that is available in literature and I would strongly recommend that you actually go through those materials if we want more information.

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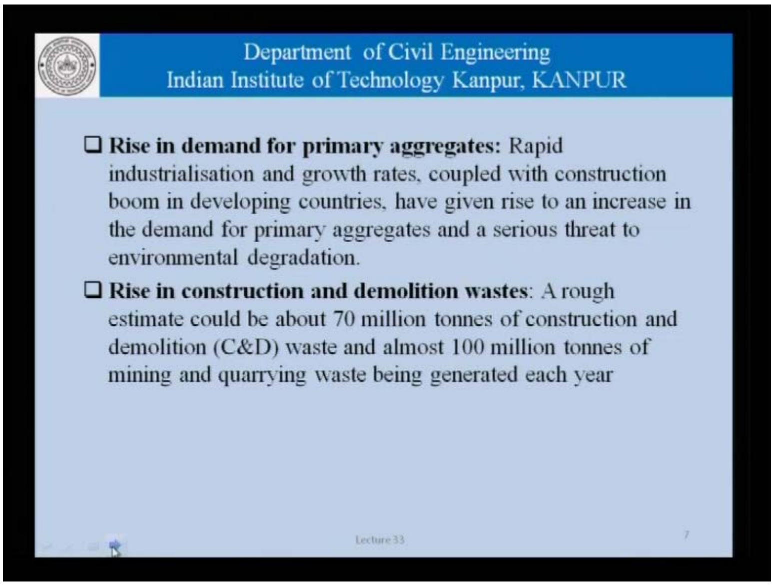

Now, why do we get involved with the business of moving recycled concrete as aggregates. The first side of the discussion is a rise in demand for primary aggregates that is, rapid industrialization in growth rates, coupled with construction boom in developing countries has given rise to an increase in the demand for primary aggregates and the serious effect to environmental degradation.

Aggregates at the end of it come from rocks and if we want coarse aggregate we basically land up destroying a certain part of the environment and the environmentalist is lists do not particularly like that and we as responsible citizens of the society have a responsibility towards environment and we should be careful when we decide to use natural resources which are finite. So, this is the demand side effect that is, more construction we want to do more aggregates we will need.

The other side of it is that there is a rise in the construction in demolition waste. A lot of our infrastructure the world over is more than say 50, 60, 70 years old and that infrastructure needs to be replaced. As a result of that once we are demolition that infrastructure lot of it being made of concrete, a rough estimate cells that about 70 million tons of construction and demolition waste and almost 100 million tons of mining and quarrying waster is being generated every year.

Now, there is a need to be able to identify ways and means by which this construction and demolition waste can be used because if we use this, the pressure on using the natural resources for any construction reduces to that extent. So, these are the two driving forces that drive us to using recycled concrete as aggregate or construction demolition wastes as aggregate.

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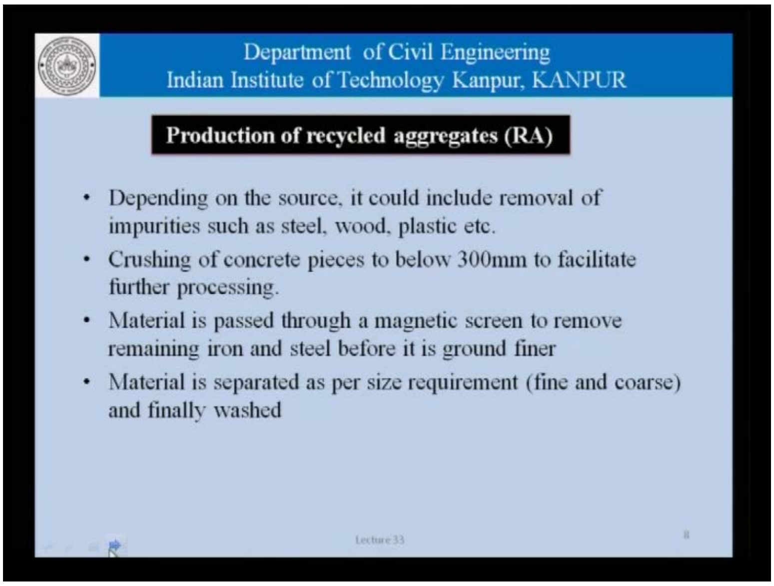

As far as the production of recycled aggregates which we are calling RA is concerned, depending on the source it could include removal of impurity such as steel, wood, plastic, bitumen and so on. So, recycled aggregate once we are trying to produce it does not come as a pure rock, it will contain impurities which could be steel or wood or plastic or bitumen depending on what is the source of this recycled aggregate.

Crushing of concrete pieces to below 300 mm to facilitate further processing. So, basically what happens is that when we are demolishing a structure we generate large pieces or chunks of concrete. The first step is to break them down you say 300 mm and then try to process them further so that it becomes easier to handle.

We need to pass the material through a magnetic screen to remove any remaining iron and steel before it is ground finer. So, the process of producing recycled aggregate is largely similar to that of producing natural aggregate or new aggregate except that a new aggregate we do not have to be so particular about the moving inherently present impurities. But, the process of crushing, washing, sieving and so on is largely resign. Of course, finally the material needs to be separated as per size requirement in terms of fine material or coarse material and finally it is washed in order that it is ready or use as a recycled aggregate.

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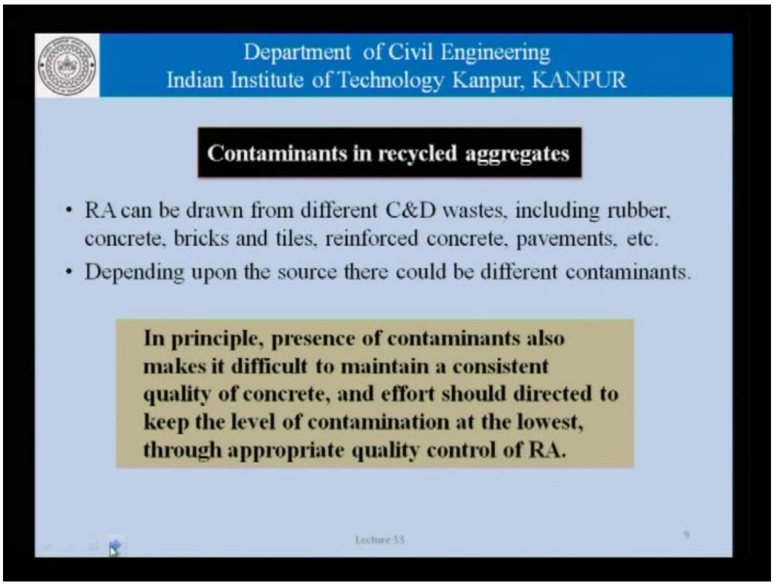

Now, what the contaminants in the recycled aggregate could be, depends on the source of the recycled aggregate. Recycled aggregate can be drawn from different construction and demolition wastes including rubber, concrete bricks and tiles, reinforced concrete, pavement and so on.

So, now depending on what is the source of our recycled aggregate the impurities or contaminants would be different and of course, depending on some other sources there could be different contaminants. But, basically in principle the presence of contaminants makes it difficult to maintain a consistent quality of concrete and efforts should be directed to keep the level of contamination at the lowest through appropriate quality control of the recycled aggregate itself.

Basically, we need to remember that as much as the properties of coarse aggregate effect the properties of the concrete so, also will the properties of the coarse aggregate or recycled coarse aggregate in this case effects the properties of the final concrete. And now since, the recycled aggregate have different contaminants different possess through which they are being produced it is likely that the variation in the properties of the recycled aggregate is a lot more than we normally expect in the case of normal aggregate and that is what makes them marginal materials. They will not pass a strict compliance test for good quality material but, that does not mean that they cannot be used in certain applications. And therefore, we need to study this subject in slightly greater detail and today's discussion is basically a bird's eye view on what really needs to be done in order that the use of recycled aggregate can be accomplished in construction projects.

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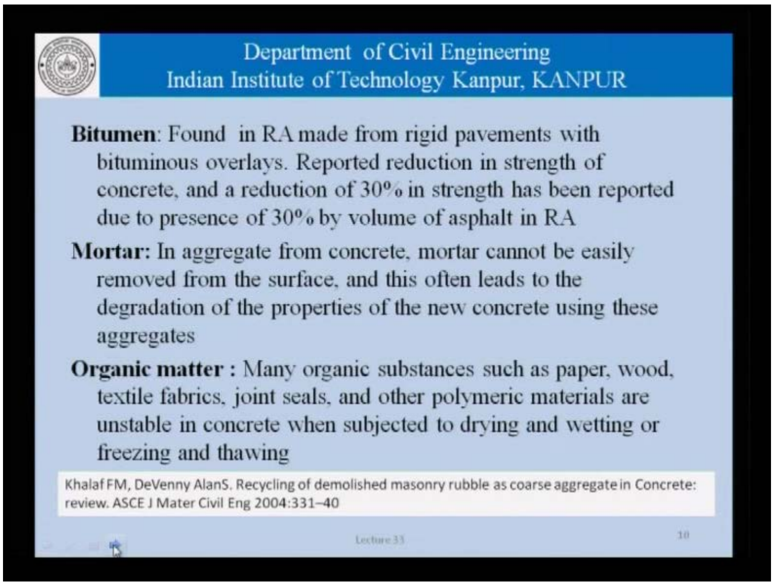

Now, coming to few impurities that are present or that could be present in recycled aggregate. One is bitumen. Now, this will be found in recycled aggregate made from rigid pavements with bituminous overlays. Reported reduction in strength of concrete and a reduction of 30 percent strength is been reported due to the presence of 30 percent by volume of asphalt in recycled aggregate.

One must remember that the resin economic issue involved. It is possible for example, to remove all asphalt which is adhering to a concrete aggregate but, that will be the process all that more expensive. So, that is a compromise between saying that okay, I am willing to except up to 5 percent of as fault adhering to my coarse aggregates provided I know that that adhesion leads to a certain reduction in strength of the concrete that is the reduction in strength or a certain amount of reduction in their strength of the concrete that I am going to use.

Mortar is a very common ingredient that will be adhering to the aggregates and it comes in aggregates from concrete. Normal concrete if we break it down and try to use a new concrete as coarse aggregate of fine aggregate will have mortar adhering to the old aggregates because mortar cannot be easily removed from the surface and this often leads to a degradation in the properties of the new concrete using these aggregates.

So, it is the extent of reduction of these properties or the extent of the compromise that we are making that becomes very very crucial and that is so important and so case specific that it is important that the engineers actually carry out tests and that has been the emphasis throughout the discussion in this module that there is no substitute for actual testing of materials and the properties of the concrete.

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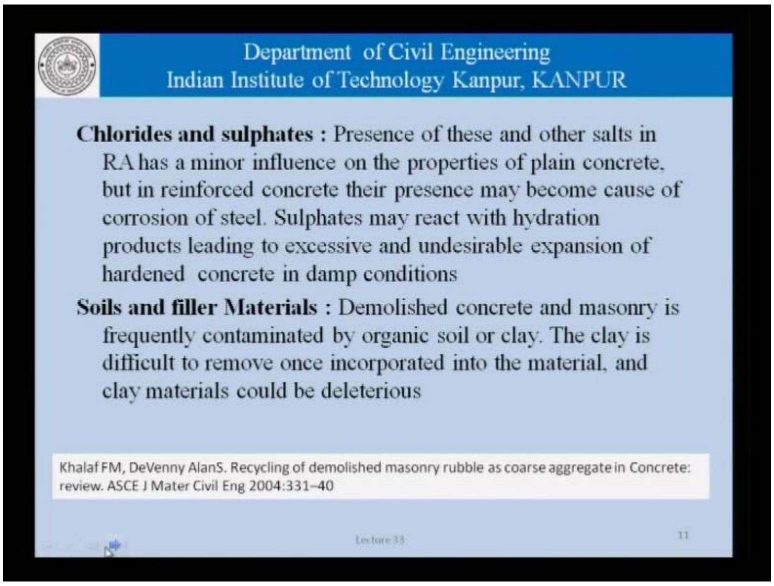

Organic matter is another contaminant in recycled aggregate and many organic substances such as paper, wood, textile, fabrics, joint seals and other polymeric materials are unstable in concrete when subjected to drying and wetting or freezing and thawing. Continuing our discussion on contaminants in recycled aggregates. There chlorides in sulphates and possibly other chemicals. Presence of these and other salts in recycled aggregate has a minor effect on the properties of plane concrete but, in reinforced concrete their presence may become the cause for corrosion steel. Sulphates may react with the hydration products leading to excessive an undesirable expansion of hardened concrete especially in damp conditions.

There is a possibility that soil and filler materials may be part of recycled aggregate system. Demolished concrete and masonry is frequently contaminated by organic soil or clay and the clay is difficult to remove once in cooperated with the material and clay materials could be deleterious. The whole idea is that understanding that what we are using is not necessarily the best quality material, what is the level of strength or any other property of concrete that we can still get. That is the subject of study.

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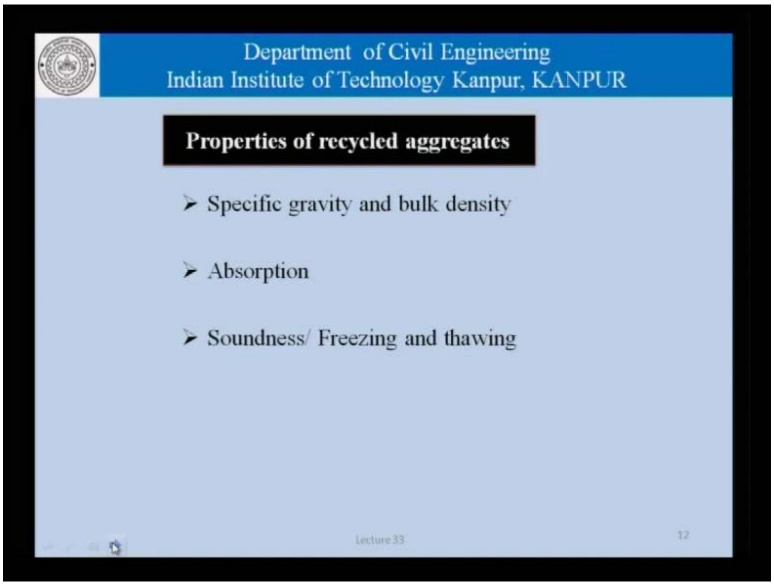

So, first step in the process is the properties of the recycled aggregates themselves. As usual the properties are nothing different, the specific gravity bulk density, absorption, soundness and freezing and thawing. These are some of the qualities of the aggregate which will be relevant whether we are using recycled aggregate or we are using normal aggregates.

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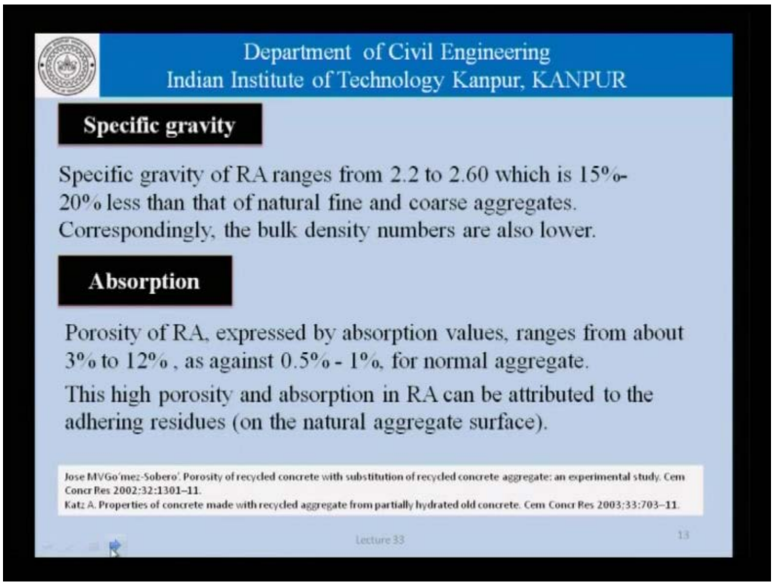

So, as far as specific gravity is concerned, the specific gravity of recycled aggregates ranges from 2.2 to 2.6 which is about 15 to 20 percent lower than that of natural final coarse aggregates. And correspondingly of course, the bulk density numbers will also be lower.

Then, we come to absorption. Now, the porosity of recycled aggregates expressed by absorption values ranges from about 3 to 12 percent as against 0.5 to let us say 1 percent in the case of normal aggregate. This high porosity and absorption and recycled aggregates can be attributed to adhering residues on the natural aggregate interface. So, this contaminants which are present on the surface of the old aggregates they become primary absorbers and since we are actually evaluating the recycle material the absorption values on the face of it increase.

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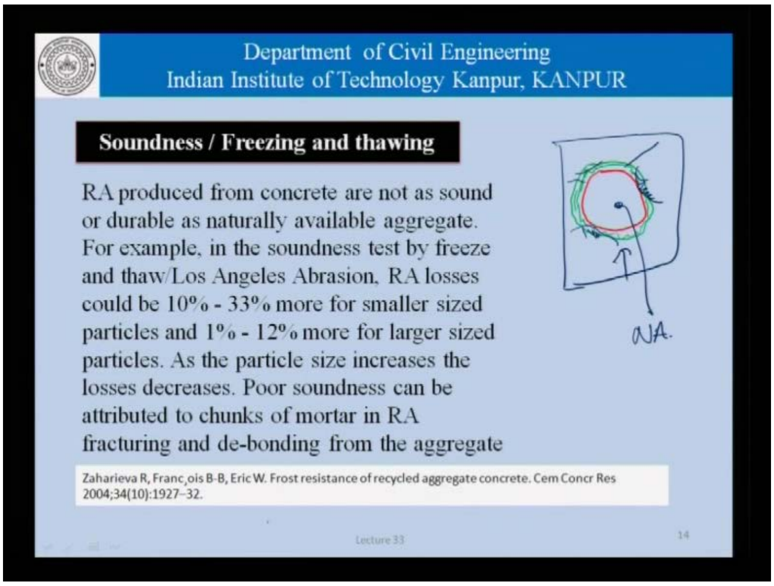

Now, let us come to soundness and freezing and thawing of the recycled aggregates. Recycled aggregates produce from concrete are not as sound or durable as naturally available aggregate. For example, in the soundness test by the freezing and thawing or the Los Angeles abrasion tests the recycled aggregate losses could be 30 to 33 percent more for smaller size particles and 1 to 12 percent more for larger size particles.

As the particle size increases the losses decrease. Poor soundness can also be attributed to chunks of mortar in recycled aggregates fracturing and de-bonding from the aggregate. See, what is really happening is that we have a normal aggregate like this and we have some contaminant deposit on the aggregate and once this recycled aggregate is tested. For example, in Loss Angeles abrasion kind of an apparatus it is likely that chunks of this mortar which is adhering to the surface of this aggregate could fracture or de-bond or just spall of and so on. As a result of that the net change in weight of this recycled aggregate will be a lot more than if we were testing simply this old natural aggregate. So, it is a matter of understandings, what is the extent of loss and this loss will obviously be related to how much is the mortar that is adhering to this aggregate and what are the qualities of that mortar, what is the strength of that mortar itself. If that mortar was high strength mortar then possibility is that extent of reduction will be small but, if the mortar which is adhering to the aggregate did not have sufficient strength then, we could have a much larger reduction in weight if were testing the recycled aggregate for Los Angeles kind of test.

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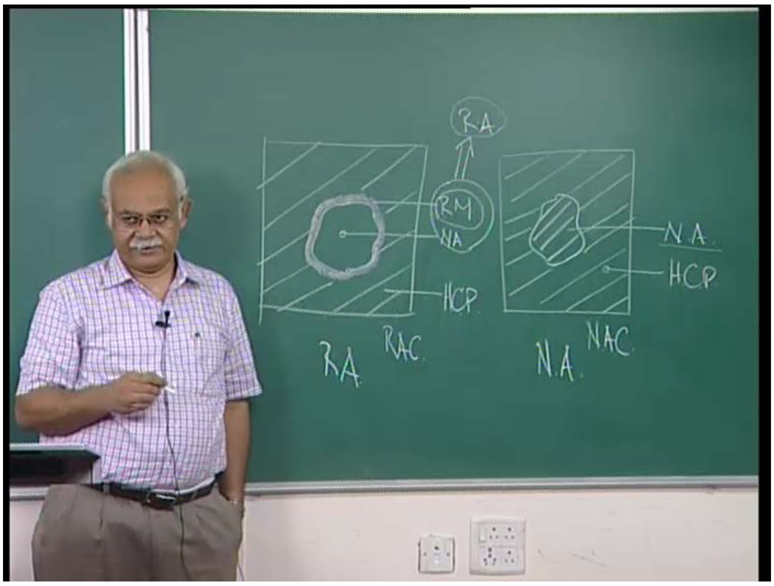

Now, this picture here shows the construction using normal aggregates or normal aggregates in concrete. We have a normal aggregate or a natural aggregate embedded in a matrix of hardened cement paste. As against this picture here is that of recycled aggregate again embedded in hardened cement paste.

So, because it is recycled it has a certain amount of residual mortar or any other contaminant adhering to the surface of the natural aggregate. This aggregate which is the natural aggregate plus residual mortar this is what we are calling recycled aggregate. Now, once this recycled aggregate is embedded in the hardened cement paste we get a concrete which could be called concrete made with recycled aggregate or recycled aggregate concrete.

Whereas, here what we will get in is natural aggregate concrete. Now, obviously the properties of this concrete and the properties of this concrete will be affected by the properties of this residual mortar. What is the actual effect on the properties of concrete would depend on the properties of this residual mortar and how much of it is adhering to the surface aggregate. This understanding should be the bases or can be the bases of understanding or trying to explore the properties of concrete which is made with recycled aggregate.

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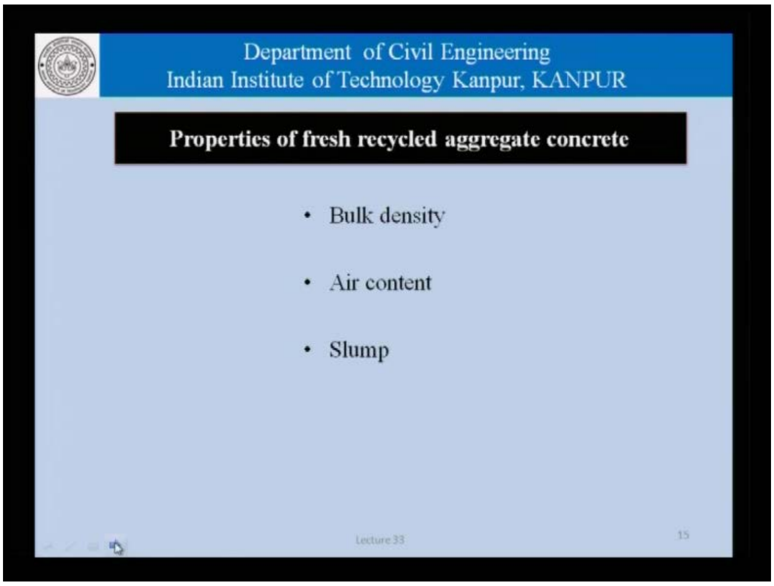

As usual when it comes to concrete may be recycled aggregates, we will talk about properties of fresh concrete and properties of hardened concrete because that understanding of concrete that concrete is a material which behaves differently when it is fresh and differently when it is hardened that does not change. Simply because we are using one aggregate type or another. So, as far as fresh concrete is concerned there are issues related to bulk density, air content and slump.

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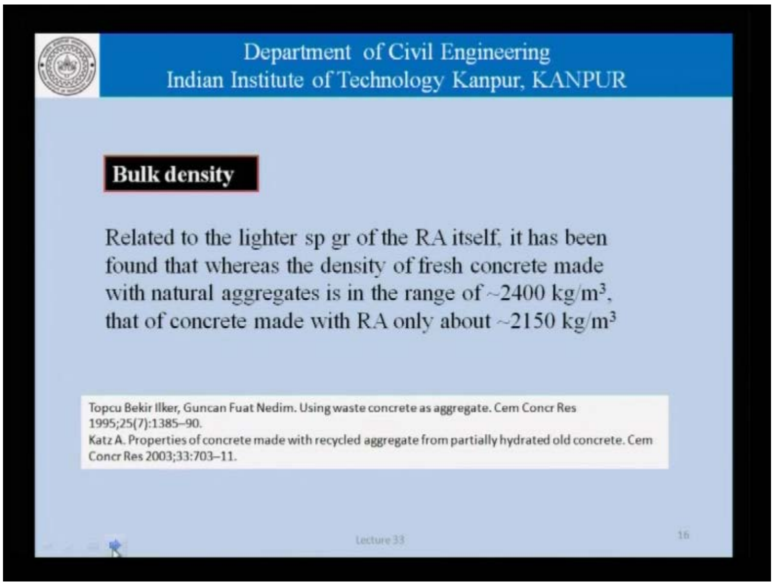

And as far as bulk density is concerned, it is related to the lighter specific gravity of the recycled aggregate itself and it is being found that whereas the density of fresh concrete made with natural aggregates is in the range of about 2400 kg per cubic meter that of concrete made with recycled aggregate is only about 2100 or 2150 and so on.

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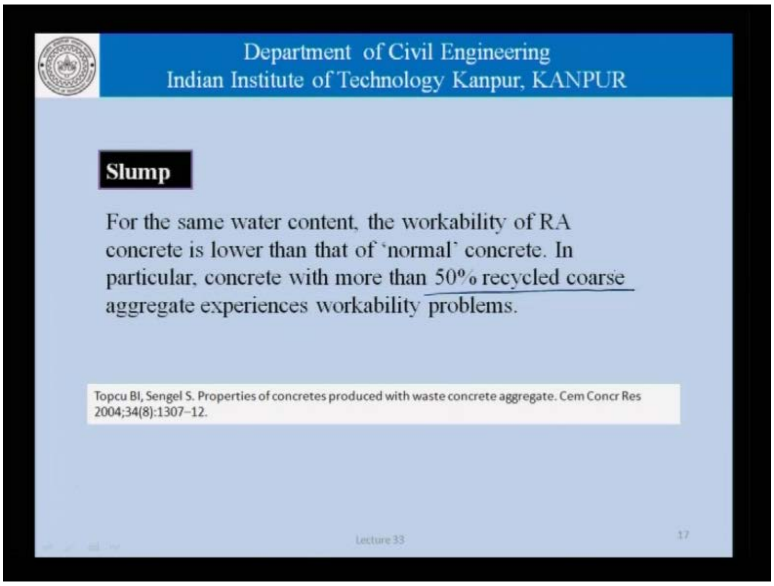

As far as the slump is concerned that is a workability of concrete made with recycled aggregates is concerned. For the same water content the workability of recycled aggregate concrete is lower than that of normal concrete that is, concrete made with normal aggregates.

In particular concretes with more than 50 percent recycled coarse aggregate experience workability related issues. So, for the first time today we are talking in terms of 50 percent recycled coarse aggregate. That is to say, there is always a possibility that the naturally occurring aggregates and the recycled aggregates are mixed and we produce concrete which has different levels of replacement of natural aggregate by recycled aggregates. We may add 10 percent, 20 percent and so on and so forth.

So, it is not necessary that any concreting situation we have a 0 1 situation that is, either use recycled aggregates or use natural aggregates. No, we can use combinations and as the results work here shows that if we use more than 50 percent recycle aggregates there could be issues related to workability.

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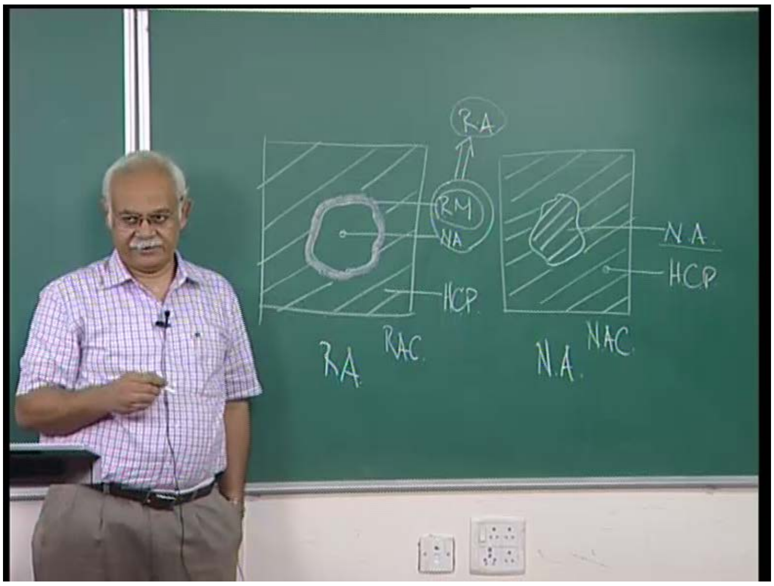

We go back to this understanding of concrete. As far as workability is concerned the effect of this residual mortar will again start to manifest itself whether it is fresh concrete or it is hardened concrete because the recycled aggregate is lighter, the concrete will be lighter. And it is lighter because very lightly whatever is adhering to the aggregate especially in cases of aggregates derived from concrete waste is mortar and has a certain amount of porosity.

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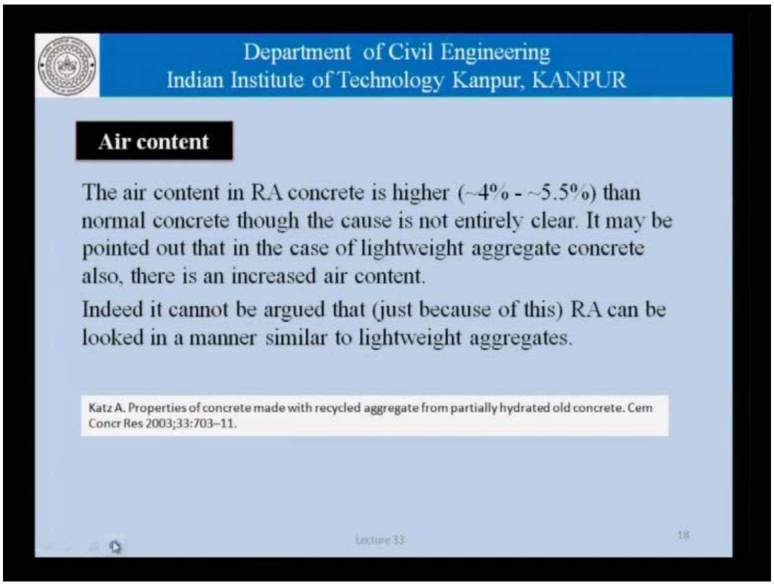

As far as the air content in recycled aggregates is concerned it has been reported that air content tends to be slightly higher than in normal concrete though the cause is not really clear. It may be pointed out that there is literature which suggests that in the case of lightweight aggregate concrete also there is a tendency for increased air content but, that does not mean that we can start treating recycled aggregates simply as another form of lightweight aggregate.

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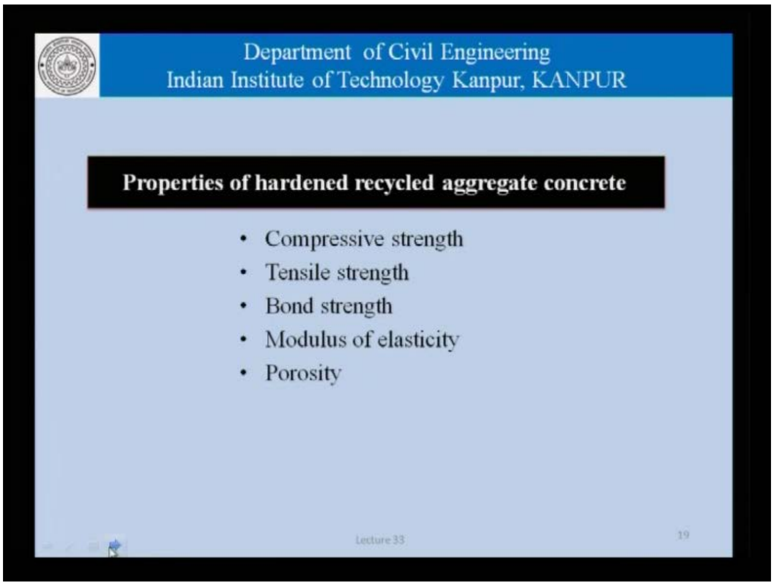

Now, coming to the properties of hardened recycled aggregate concrete. We have the same old properties compressive strength, tensile strength, bond strength, modulus of elasticity, porosity and so on.

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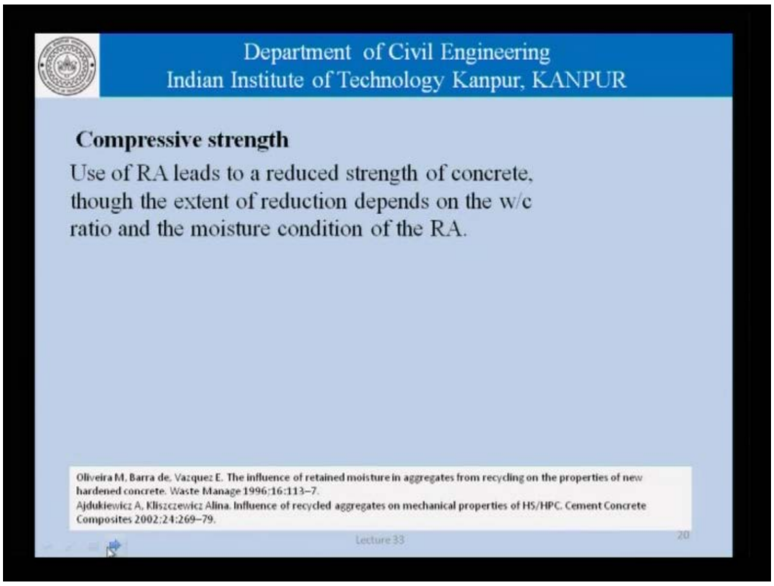

As far as compressive strength is concerned the use of recycled aggregate leads to a reduced strength of concrete and of course, the extent of reduction depends on the water cement ratio and the moisture condition of the aggregate.

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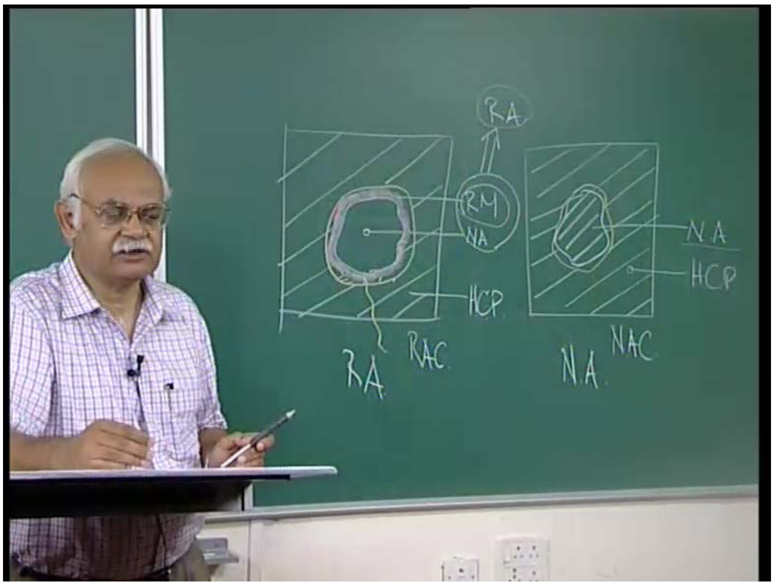

What is being said here is that depending on the water cement ratio of this hardened cement paste and the moisture conditions of the recycled aggregate that is to what extent was this mortar which was adhering to the virgin aggregate. To what extent was that saturated whether, this contaminant would absorb or release water into the hydrated cement paste that will determine the effect of using recycled aggregates on the strength of concrete.

The whole idea here when we were using or discussing natural aggregates and their segregation in concrete was that there is an into measure transition zone or an interfacial transition zone which is formed around the aggregates which often tends to govern the properties of concrete as far as strength is concerned.

Now, in the case of recycled aggregate, how do we interpret or what kind of understanding do we carry as far as that ITZ is concerned because we already have one ITZ in the form of mortar which is adhering to the original aggregate. And there will be another ITZ which will be formed around this in much the same manner as an ITZ would form here. And since, this discussion is largely qualitative and it cannot be made more quantitative very easily, it is important that if we decide or when we decide to use recycled aggregates in our concrete we carry out the actual test and find out what is the level of reduction of strength or the change in any other property that we are talking about.

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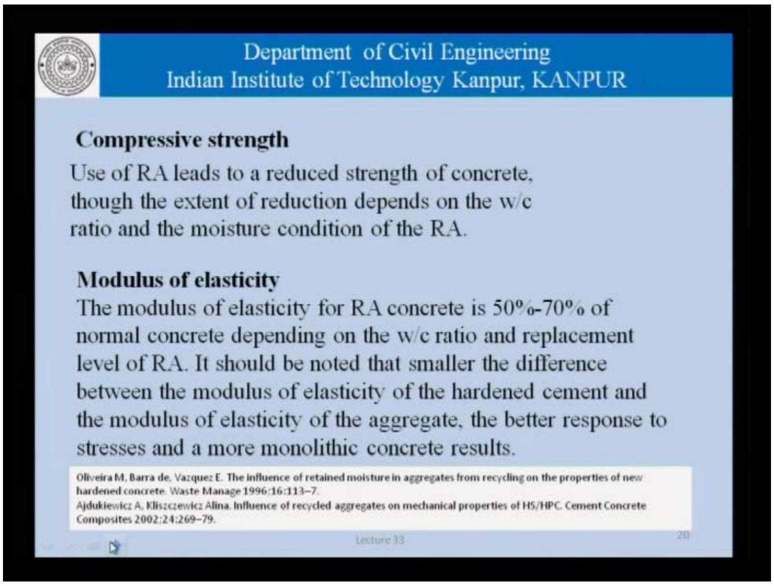

Now, let us come to the modulus of elasticity. Now, the modulus of elasticity of the recycled aggregate is about 50 to 70 percent of the normal concrete depending on the water cement ratio in the replacement level and this issue we have more or less discussed just now. It should be noted that smaller the difference between the modulus of elasticity of the hardened cement and the modulus of elasticity of the aggregate, the better is the response of the concrete made with recycled aggregate to stresses and the more monolithic concrete.

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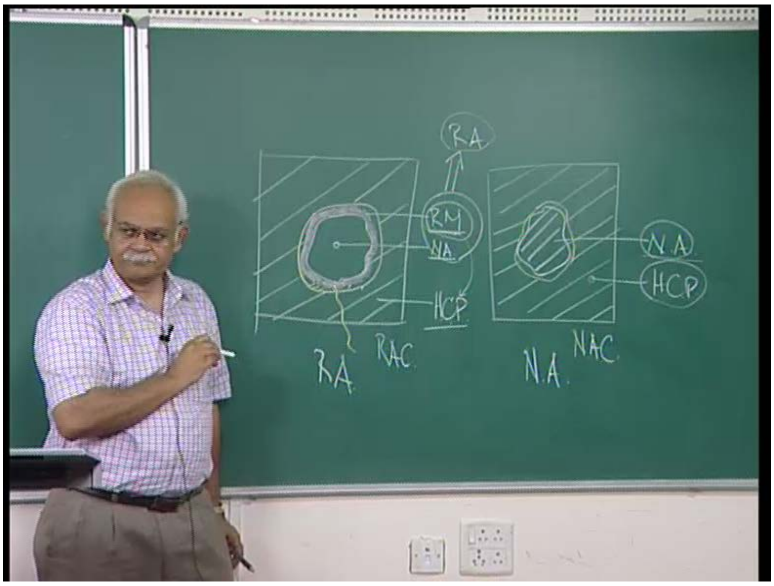

As far as the modulus of elasticity of this concrete is concerned that obviously is related to the modulus of elasticity of the hardened cement paste and the modulus of elasticity of the natural aggregate. So, in this case the modulus of elasticity would depend on the modulus of elasticity of this, this, this together. If the modulus of elasticity of this material is close to the modulus of elasticity of this material then, any reduction or change in the e values of this concrete would be lower compare to a situation where this material is substantial weaker or stronger compared to this.

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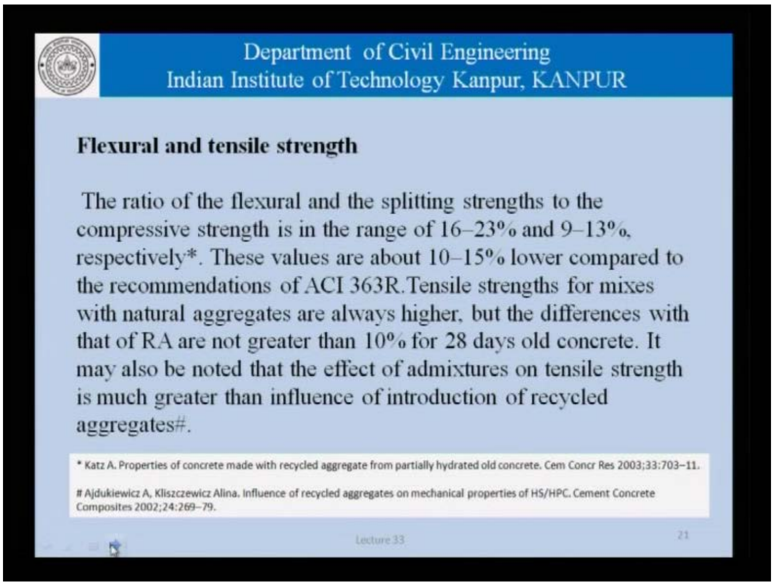

Now, as far as flexural tensile strength is concerned and that is something which we use that we are trying to use concrete and applications like pavements and so on. The ratio of the flexural and splitting strength to the compressive strength is in the range of 16 to 23 percent and 9 to 13 percent respectively.

These values are about 10 to 15 percent lower compared to the recommendations of the ACI 363. And the tensile strength for mixes with natural aggregates are always higher but, the difference with that of the recycled aggregates are not greater than 10 percent at 28 days of concrete. It may be noted that the effect of admixtures and tensile strength is much greater than the effect of introduction of recycled aggregates.

So, basically the idea is that the tensile strength and flexural strength values are much smaller compared to compressive strength values. And therefore, it is difficult to study those properties with as much clarity as we can as far as compressive strength is concerned. Nonetheless, we must make an effort actually determine these values and find out how different they are compare to normal aggregates or what are the actual that we will get at site depending on application so that, that is the value that the designer is aware of when he carries out the structural design.

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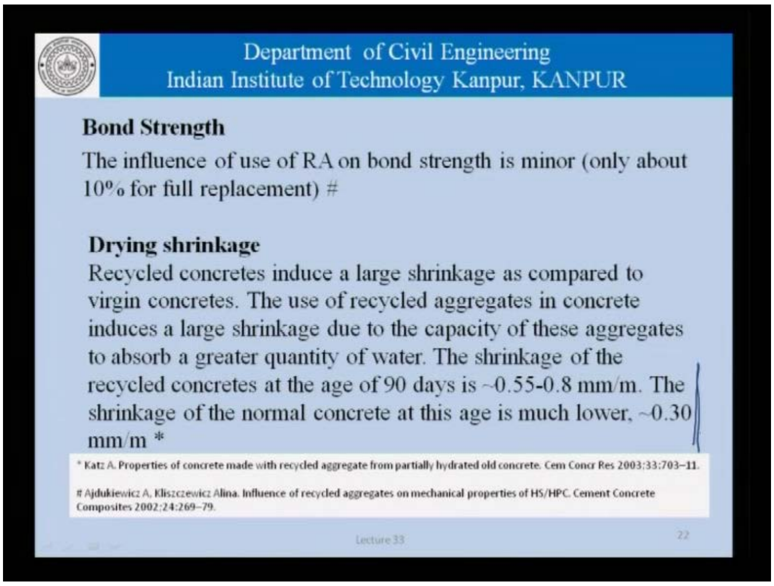

Now, continuing with our discussion on the properties of concrete affected by the use of recycled aggregates, let us talk about bond strength. The influence of using recycled aggregate on bond strength is minor and only about 10 percent at full replacement.

Now, as far as drying shrinkage is concerned, recycled concretes or concretes made with recycled aggregates induce a large shrinkage or a larger shrinkage as compared to concretes made with normal aggregates. The use of recycled aggregates in concrete induces a large shrinkage due to the capacity of these aggregates to absorb greater quantities of water. The shrinkage of recycled aggregate concrete at the age of about say 90 days is 0.55 to 0.8 millimeters per meter. And the shrinkage of normal concrete at this level is only about 0.3. So, now there is no reason to take these values as [sacrosand] truth.

These are the results of an experiment investigation carried out under certain conditions. What it only points out is that, depending on the quality of the recycled aggregate there could be issues relating to drying shrinkage and once the engineer is aware of that the structure can be designed accordingly.

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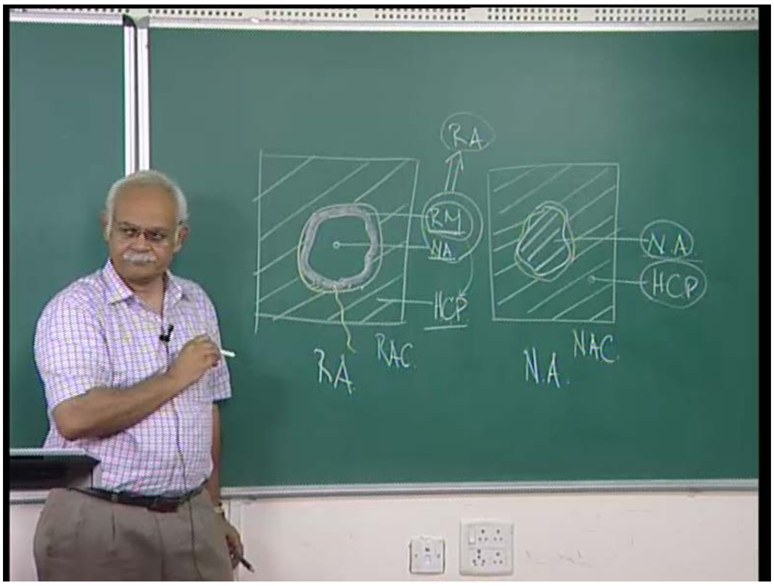

As I explained here the absorption of water in the case of concrete being made with recycled aggregate occurs not only in the hardened cement paste but, also in the residual material and that is why the drying shrinkage is higher.

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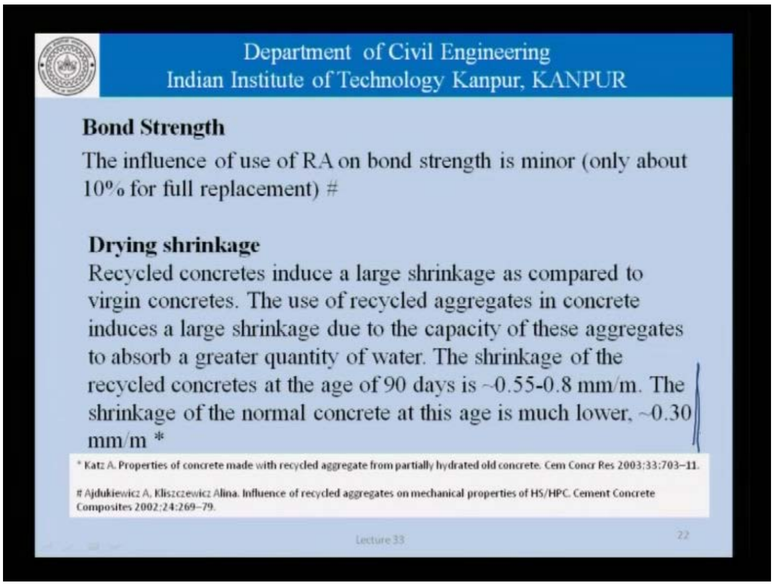

In all this discussion we should remember that we are talking of the residual material being such that it absorbs water, it has certain porosity much like mortar. We are normally talking in terms of recycled aggregate made from old concrete. This discussion would change slightly if the material or the recycled aggregate was drawn from bituminous concrete and instead of mortar the normal cement mortar that we are familiar with it was bitumen which was adhering to the virgin aggregate and that aggregate was being used in recycled aggregate concrete. So, that discussion would change slightly but, in principle the fact that we must test or determine the effect of using recycled aggregate concrete on compressive strength or tensile strength or drying shrinkage or bond strength that fact does not still go away.

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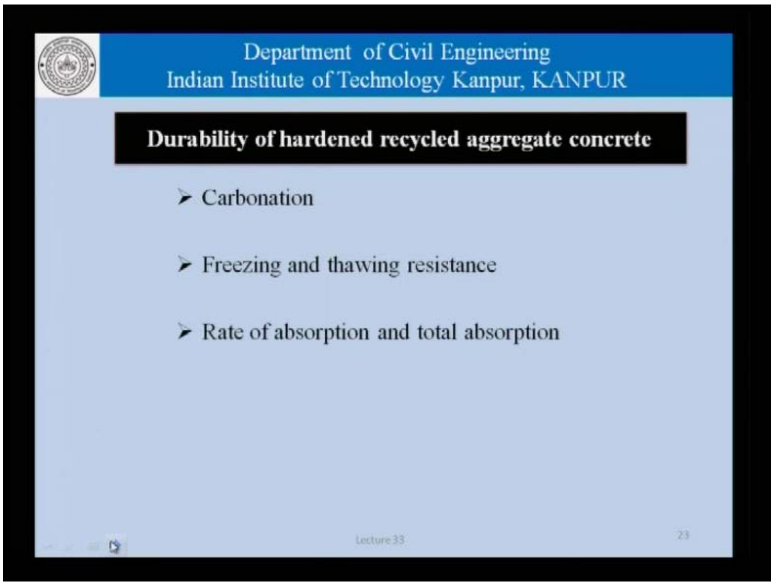

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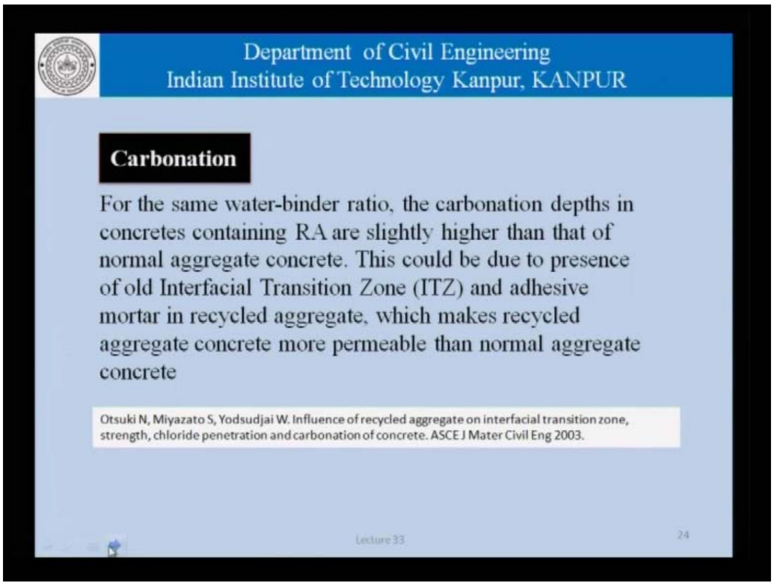

Another aspect or may be last aspect as far as the use of recycled aggregate in concrete is concerned is that related to durability and again we are concerned with carbonation studies, freezing and thawing resistance and the rate of absorption and total absorption of concrete.

As far as carbonation is concerned for the same water pointer ratio the carbonation depths in concrete containing recycled aggregates are slightly higher than that of normal aggregate concrete and this could be due to the presence of old interfacial zone or interfacial transition zone the ITZ and the adhesive mortar in the recycled aggregates which makes the recycled concrete more permeable than normal aggregate concrete.

So, basically it is the same old properties that are coming to visit us. The porosity, the absorption of the aggregate coupled with the porosity and absorption of the old mortar versus the new mortar because there is no reason to believe that the residual mortar which is adhering to the cold aggregate will have the same water cement ratio or the same kind of characteristics as the new hardened cement paste which surrounds it

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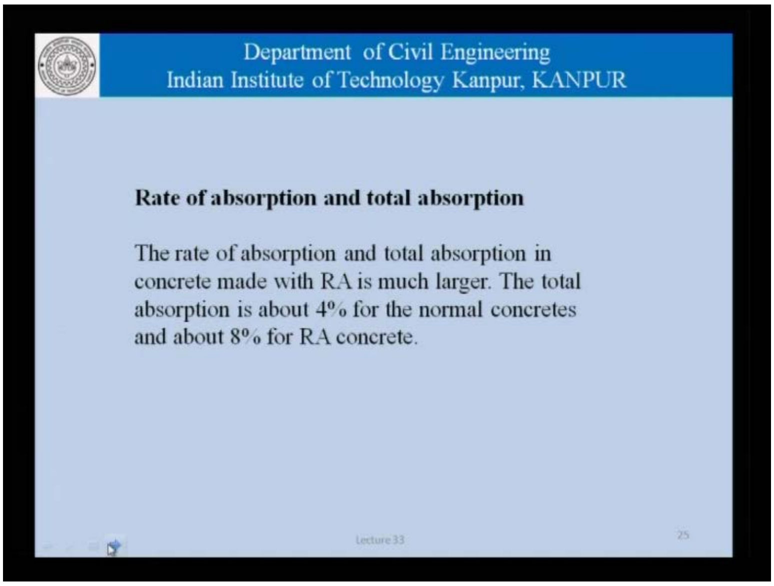

As far as the rate of absorption and the total absorption of water is concerned the rate of these properties are higher as far as recycled aggregate concrete is concerned compared to normal concrete. The total absorption is about 4 percent for normal concretes and is about 8 percent for recycled aggregate concretes.

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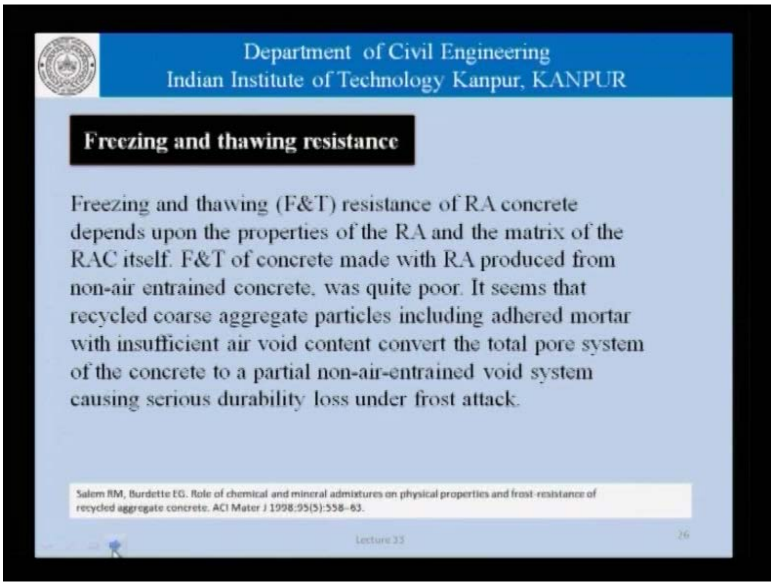

As far as the freezing and thawing resistance is concerned, this resistance of recycled aggregate concrete really depends on the properties of the recycled aggregate and the matrix of the recycled aggregate concrete itself. The freezing and thawing of concrete made with recycled aggregate produced from non air-entrained concrete is quite poor as far as this particular study that was carried out is concerned.

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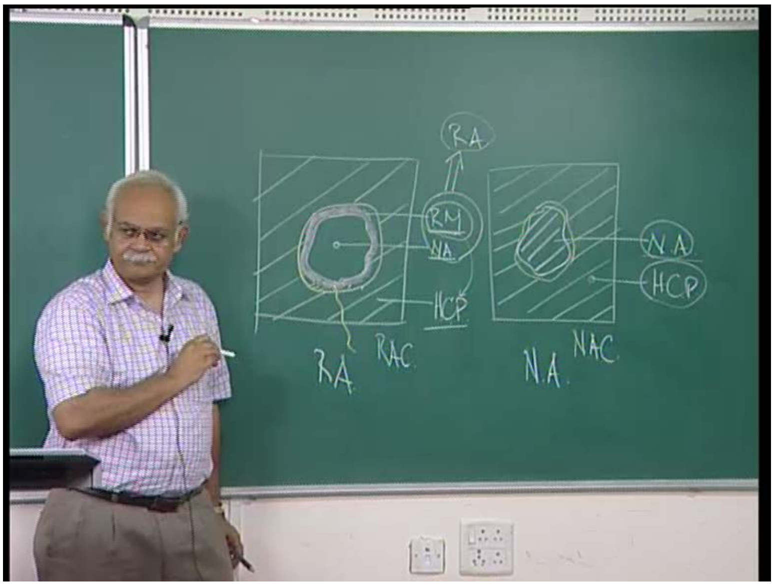

It seems that recycled coarse aggregate including particles or including adhered mortar with insufficient air void content convert the total pore system of the concrete to a partially non entrained void system and causing serious durability loss under frost attack.

So, what we are really looking at is a system which is similar to this. And as far as normal concrete is concerned when that is exposed to freezing and thawing, it is the porosity or the air entrainment in this hardened cement paste which matters. When it comes to concretes made with recycled aggregates. What air content are we talking about? Are we talking about air content here which is what will happen which is what we will possibly measure or try to ensure when we are making concrete made with the recycled aggregate or we are trying to talk about the air content of this residual mortar which is adhering to the concrete or which is adhering to the cold aggregate.

Now, it is a combination of this air entrainment and this entrainment that is going to find the determinant. The air entrainment or the durability of this concrete in freezing and thawing.

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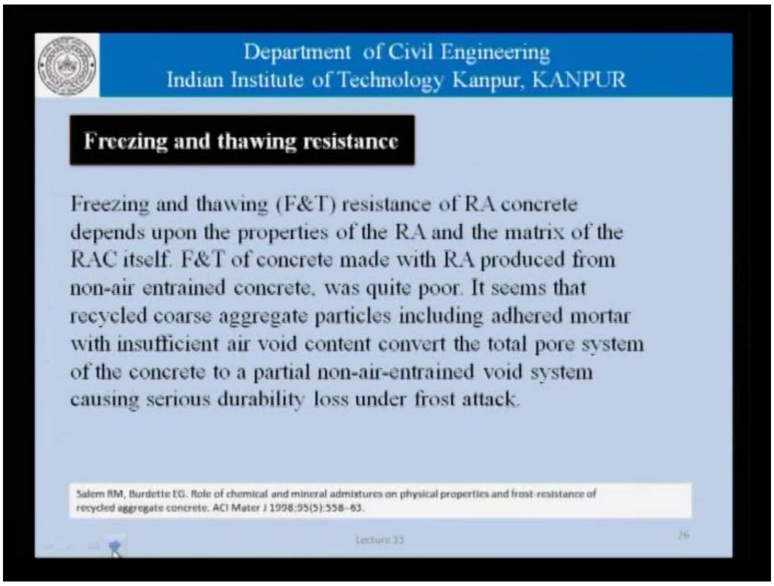

Now, before we conclude our discussion have been gone through the properties of the recycled aggregate itself and also the properties of the concrete that is made with that recycled aggregate and having covered briefly the need to study this issue of using recycled aggregate.

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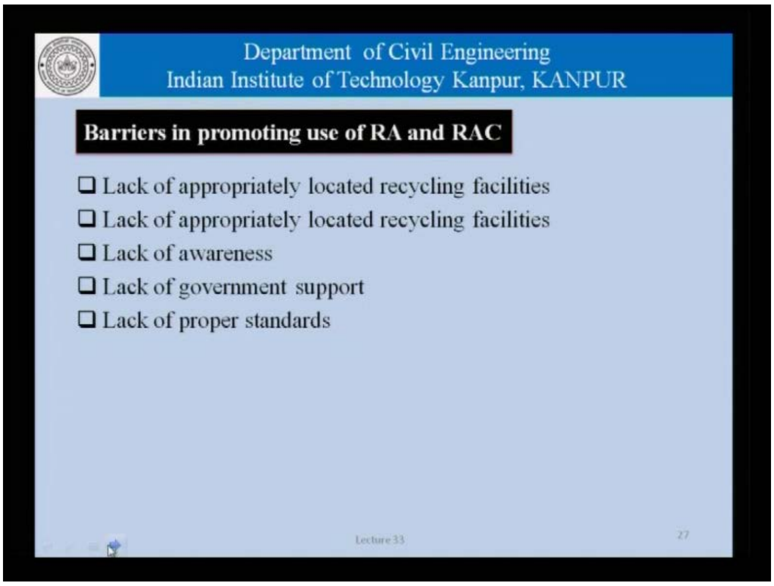

What are the barriers in promoting the use of recycled aggregate and concrete made with recycled aggregate? Now, the first thing that we have is a lack of appropriately located recycling facilities. The second is a lack of awareness among concrete engineers and users towards the use of recycled aggregate as a construction material. Then, there is lack of government or regulatory support and a lack of proper standards that define precautions that must be taken or the conditions in which such material can be used.

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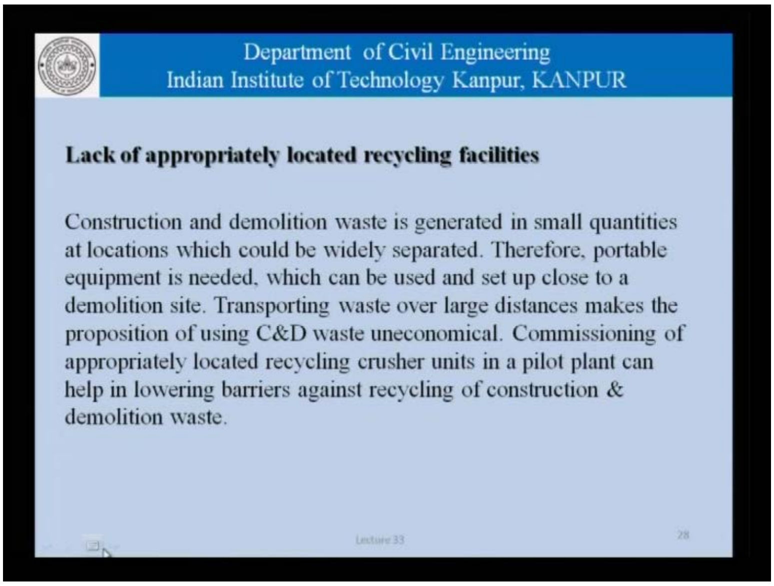

Now, if we spend a while on each of these issues as far as the lack of appropriately located recycled facilities is concerned, we must be aware that construction and demolition waste is generated with small quantities at locations which could be widely separated. Therefore, portable equipment which can convert the demolition waste locally into aggregates is needed and that equipment can be set up closed to a demotion site. Unlike a normal quarrying where the entire process of crushing, sieving and so on takes place at a particular place and the aggregates is transporting.

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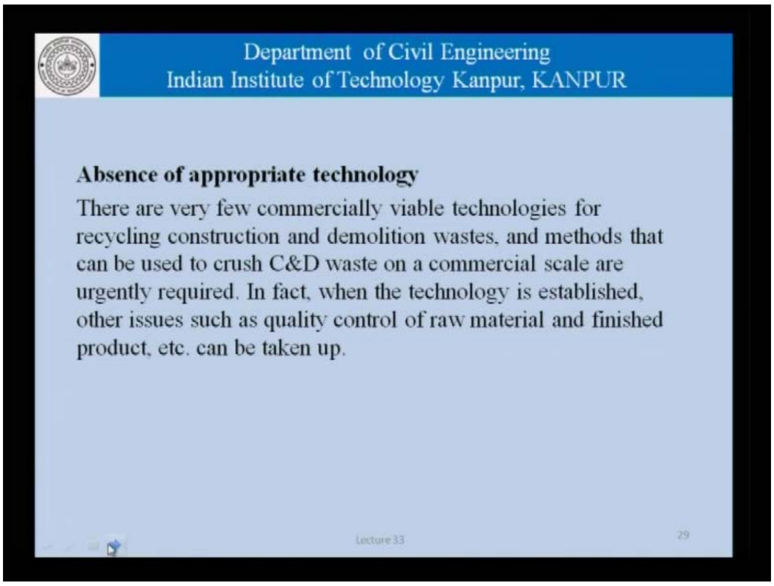

Transporting ways to the larger distances makes the preposition of using construction demolition waste uneconomical and commissioning of appropriately located recycling crusher units in a pilot plant can help in lowering barriers against recycling of such waste. Then, there is of course, the absence of appropriate technology as well. There are very few commercially viable technologies for recycling, construction in demolition waste and the methods that can be used to crush the C and D waste on a commercial scale are urgently required and I think one of the things that we need to do as far as engineers is concerned is to develop such technologies. In fact, when the technologies established other issues such as quality control of raw material and finished product as far as the recycled aggregate is concerned can obviously be taken up.

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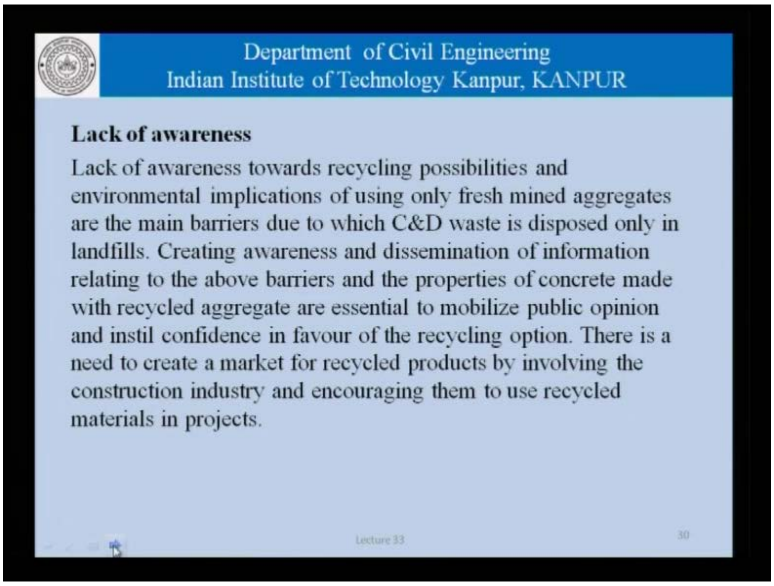

Lack of awareness among the users and the engineers is a large barrier towards using these materials in actual construction. Lack of awareness towards recycling possibilities in the environment will implications of using only fresh mind aggregates are the main barriers due to which construction demolition waste is disposed only in landfills and is not used as a construction material.

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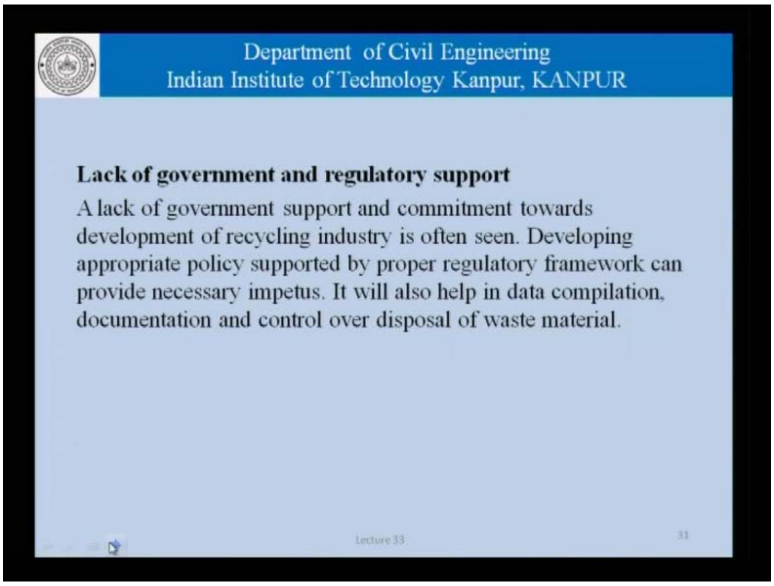

Creating awareness in dissemination of information relating to these barriers and the properties of concrete made with recycled aggregate are essential to mobilize public opinion and instill confidence in favour of the recycling option. There is a need to create market for recycled products by involving the construction industry and encouraging them to use recycled materials in projects.

And that cannot happen unless we have a regulatory support or a government support. A lack of government or regulatory support and commitment towards development of recycling industry is often seen as a barrier. Developing appropriate policy supported by proper regulatory framework can provide the necessary impetus to use recycled aggregates in the construction industry and it will also help in data compilation, documentation and control over disposal of waste material.

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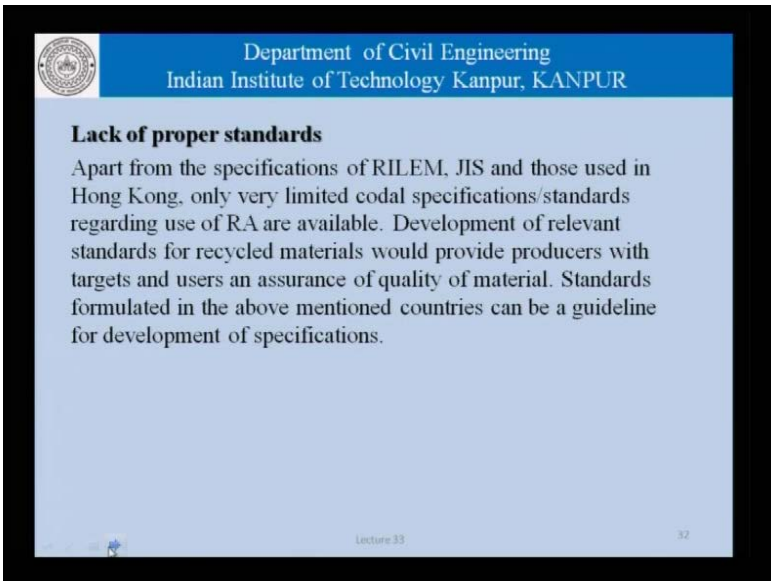

As far as standards is concerned that is the first step which gives confidence to a user and and to an engineer in using these materials and very few specifications are available in the world today. Rilem, Jis and some of those used in Hong Kong are only the beginning and a lot more needs to be done before such specifications are in place which will enable the use of recycled aggregate concrete. But, as far as the discussion is concerned today is relevant to concrete engineers who will be practicing for a lot of years to come and that is why it is important that they are aware of the issues involved, the test that should be undertaken and identify areas in which such marginal products can be used.

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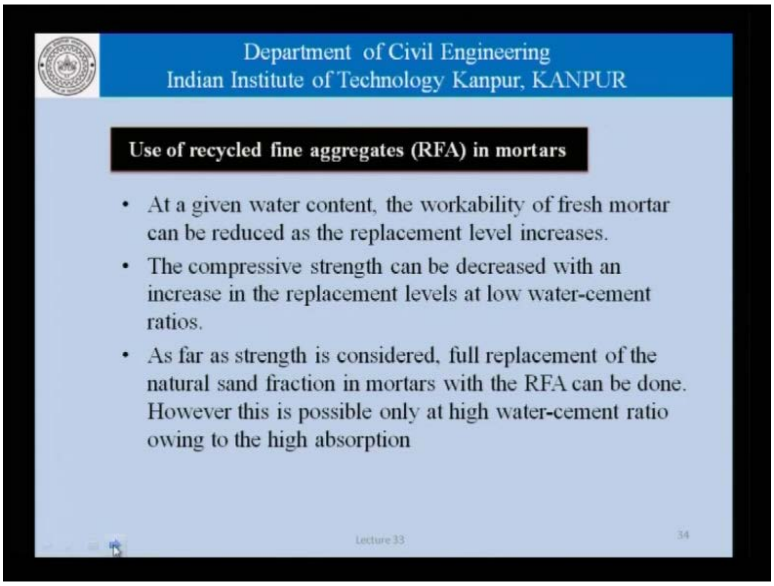

In summary, as far as the use of recycled fine aggregate mortars is concerned. At a given water content the workability of fresh mortar can be reduced as a replacement level increases. The compressive strength can go down. And as far as this strength is concerned, the full replacement of natural sand fractions in mortar with recycled fine aggregates can be done. However, it will be possible only at high water-cement ratios because of the high absorption in RFA.

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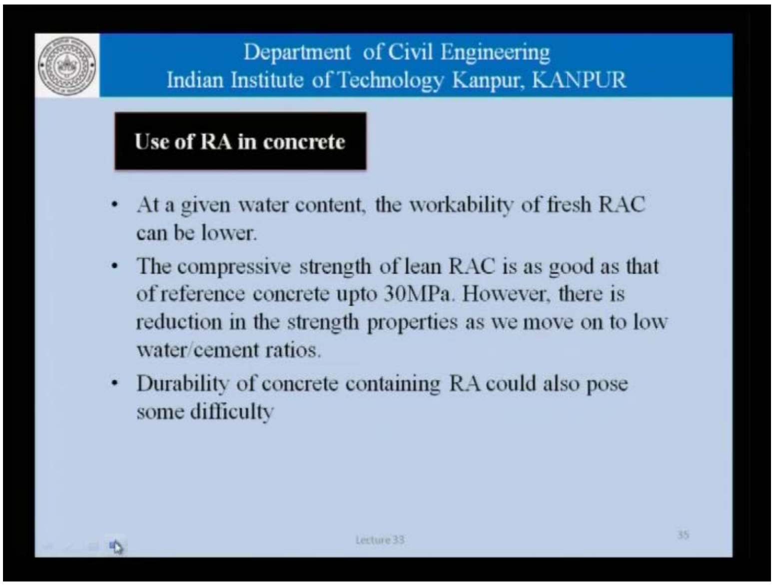

As far as concrete is concerned, at a given water content the workability of fresh concrete is lower; the compressive strength of concrete is also lower. But, it is not so much compromised so long as we are dealing with concretes up to about 30 MPa of strength. And therefore, there can be a lot of places where recycled aggregate concrete can be actually used.

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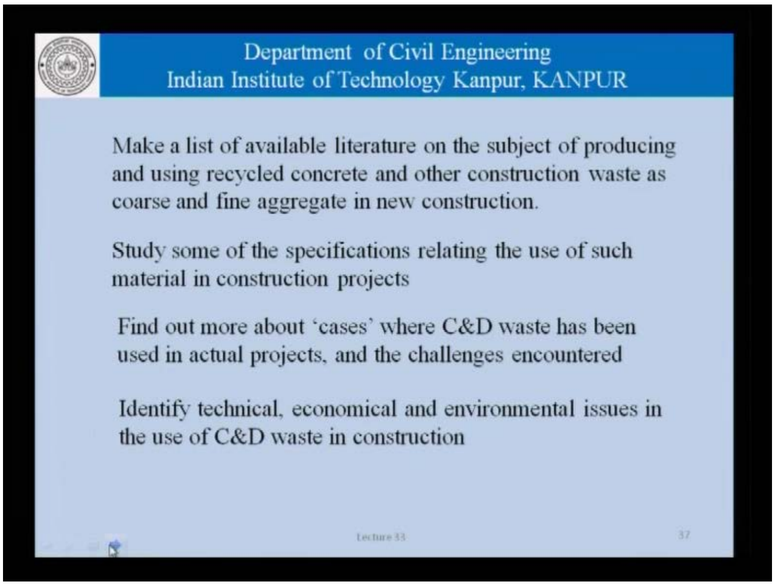

The durability of concrete could pose some difficulty but, still there are places where we could gainfully use this material. Now, before we close the discussion as usual there are a few questions for you. Make a list of available literature of the subject of producing and using recycled concrete and other construction waste as coarse and fine aggregate in new construction. Study some of the specifications related to the use of such material in construction projects. Find out more about actual cases where construction in demolition waste has been used in projects and the challenges that we encountered there. And identify technical, economical and environmental issues that are related to the use of construction and demolition waste in concrete construction.

Thank you.